Mark Scheme (Results)

October 2022

Pearson Edexcel International Advanced Level in Physics (WPH14)
Unit 4 Further Mechanics, Fields and Particles

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Mark scheme notes

Underlying principle

The mark scheme will clearly indicate the concept that is being rewarded, backed up by examples. It is not a set of model answers.

1. Mark scheme format

1.1 You will not see 'wtte' (words to that effect). Alternative correct wording should be credited in every answer unless the MS has specified specific words that must be present. Such words will be indicated by underlining e.g. '<u>resonance</u>'

1.2 Bold lower case will be used for emphasis e.g. '**and**' when two pieces of information are needed for 1 mark.

1.3 Round brackets ( ) indicate words that are not essential e.g. "(hence) distance is increased".

1.4 Square brackets [ ] indicate advice to examiners or examples e.g. [Do not accept gravity] [ecf].

2. Unit error penalties

2.1 A separate mark is not usually given for a unit but a missing or incorrect unit will normally mean that the final calculation mark will not be awarded.

2.2 This does not apply in 'show that' questions or in any other question where the units to be used have been given, for example in a spreadsheet.

2.3 The mark will not be awarded for the same missing or incorrect unit only once within one clip in ePen.

2.4 Occasionally, it may be decided not to insist on a unit e.g the candidate may be calculating the gradient of a graph, resulting in a unit that is not one that should be known and is complex.

2.5 The mark scheme will indicate if no unit error is to be applied by means of [no ue].

3. Significant figures

3.1 Use of too many significant figures in the theory questions will not be prevent a mark being awarded if the answer given rounds to the answer in the MS.

3.2 Too few significant figures will mean that the final mark cannot be awarded in 'show that' questions where one more significant figure than the value in the question is needed for the candidate to demonstrate the validity of the given answer.

3.3 The use of one significant figure might be inappropriate in the context of the question e.g. reading a value off a graph. If this is the case, there will be a clear indication in the MS.

3.4 The use of $g = 10\ m\ s^{-2}$ or $10\ N\ kg^{-1}$ instead of $9.81\ m\ s^{-2}$ or $9.81\ N\ kg^{-1}$ will mean that one mark will not be awarded (but not more than once per clip). Accept $9.8\ m\ s^{-2}$ or $9.8\ N\ kg^{-1}$

3.5 In questions assessing practical skills, a specific number of significant figures will be required e.g. determining a constant from the gradient of a graph or in uncertainty calculations. The MS will clearly identify the number of significant figures required.

4. Calculations

4.1 Bald (i.e. no working shown) correct answers may score full marks.

4.2 Some working is expected for full marks to be scored in a 'show that' question or an extended calculation question.

4.3 If a 'show that' question is worth 2 marks, then both marks will be available for a reverse working. If the question is worth 3 marks then only 2 marks will be available.

4.4 use of the formula means that the candidate demonstrates substitution of physically correct values, although there may be conversion errors e.g. power of 10 error.

4.5 The mark scheme will show a correctly worked answer for illustration only.

5. Quality of Written Expression

5.1 Questions that asses the ability to show a coherent and logically structured answer are marked with an asterisk.

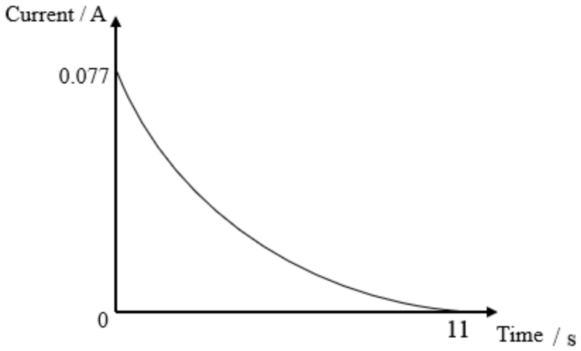
5.2 Marks are awarded for indicative content and for how the answer is structured.

5.3 Linkage between ideas, and fully-sustained reasoning is expected.

Question Number	Answer	Mark
1	The only correct answer is **B** because mass is unchanged for an antiparticle but charge is opposite. A is not correct because anti-proton charge is negative C is not correct because mass cannot be negative D is not correct because mass cannot be negative	**1**
2	The only correct answer is **C** because this was one of the main conclusions A is not correct because this was a feature of the disproved plum pudding model B is not correct because the existence of protons and neutrons was not known at this time D is not correct because the conclusion was that most of the atom was empty space	**1**
3	The only correct answer is **A** because this is the correct description of thermionic emission B is not correct because this helps electrons to move freely when released C is not correct because the filament is not bombarded by high-energy electrons D is not correct because the metal filament is not maintained at a high potential	**1**
4	The only correct answer is **B** because the field lines diverge (indicating alike charges) and the point where a unit charge experiences no resultant force is closer to charge X A is not correct because the null point would be equidistant between the charges C is not correct because this would create a different (attractive) pattern between the charges D is not correct because this would create a different (attractive) pattern between the charges	**1**
5	The only correct answer is **D** because this uses the formula $W = ½\ QV$ and takes account of charge being measured in nC A is not correct because this gives capacitance of the capacitor in nF B is not correct because this uses an incorrect formula C is not correct because this does not take into consideration charge being measured in nC	**1**
6	The only correct answer is **C** because this is the only option expressed solely in base units A is not correct because the newton is not a base unit B is not correct because the newton and the coulomb are not base units D is not correct because the coulomb is not a base unit	**1**
7	The only correct answer is **D** because it gives the correct charge +2e A is not correct because the charge is −1e B is not correct because this is a meson C is not correct because this is a meson	**1**
8	The only correct answer is **A** as this is required for the operation of a Linac B is not correct because particles do not gain energy in the tubes C is not correct because the p.d. between tubes is the same for successive tubes D is not correct because the time spent in eachtube is the same	**1**
9	The only correct answer is **B** because m is proportional to p^2 / E A is not correct because the mass is m C is not correct because the mass is m D is not correct because the mass is m	**1**

10	The only correct answer is **A** because an alternating magnetic field is required to induce an alternating potential difference in M B is not correct because there is no changing magnetic field C is not correct because there would be an e.m.f. of constant polarity D is not correct because there would be an e.m.f. of constant polarity	**1**

Question Number	Answer		Mark
11(a)	• Quark and anti-quark [Accept $q\bar{q}$, ignore correct examples such as $u\bar{d}$, do not accept 'quarks and antiquarks']	(1)	1
11(b)	Any **one** from • Leptons are fundamental (particles) • They cannot be broken down (into smaller particles) • They have a lepton number ≠ 0 • Lepton number = 1 or –1 • L = 1 or –1 • They have a baryon number = 0 • B = 0 [Accept – not subject to strong (nuclear) force] [Accept – subject to weak force]	(1)	1
11(c)	• Charge on X must be 0 **Or** X is neutral • Lepton number of a pion is 0 • Muon has a lepton number of +1 • X must have a lepton number of −1 4th mark dependent on all four points and a conclusion that the student is correct [Baryon number of X = 0 – not necessary for deduction, but accept as 1 mark alternative if MP1,2,3,4 not awarded]	(1) (1) (1) (1)	4
	Total for question 11		**6**

Question Number	Answer		Mark
12(a)	• Curve of decreasing negative gradient beginning at a positive current value • Initial current labelled as 0.077 (A) • Use of Time Constant = RC • Time for discharge marked as 11(.05) (s) **Or** 2.2 s marked when current has decreased to about 1/3 of initial value (0.028 A) **Or** 1.5 s marked when current has decreased to about 1/2 of initial value (0.038 A) <u>Example of graph</u>  <u>Example of calculation</u> I = V/R = 5000 V / 65×10^{3} Ω = 0.077 A $T = RC = 65\times10^{3}\ \Omega \times 34\times10^{-6}$ F = 2.21 s	**(1)** **(1)** **(1)** **(1)**	**4**
12(b)	• Use of $I_0 = V/R$ • Use of $\ln I = \ln I_0 - t/RC$ • t = 0.53 ms • Conclusion with comparison between relevant calculated quantity and corresponding value from question **Or** • Use of $I_0 = V/R$ • Use $I = I_0 e^{-\frac{t}{RC}}$ with t = 2.0 ms • I = 22.5 A • Conclusion with comparison between relevant calculated quantity and corresponding value from question <u>Example of calculation</u> I_0 = 5000/150 = 33.3 A $\ln 30 = \ln 33.3 - t/150\Omega \times 34 \times 10^{-6}$ F t = 0.53 ms which is less than 2.0 ms, so it does not meet the requirement	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**4**
	Total for question 12		**8**

Question Number	Answer		Mark
13(a)	• Use of eV to J conversion factor • Use of $\Delta E = c^2 \Delta m$ • Determines mass of Z boson = 1.62×10^{-25} (kg) **Or** mass of proton = 9.39×10^{8} (eV/c^2) • Mass is 97 times greater <u>Example of calculation</u> mass of boson $= \frac{91\ \mathrm{GeV/c^2} \times 10^9 \times 1.6 \times 10^{-19}\ \mathrm{J\,eV^{-1}}}{(3\times10^8)^2\ (\mathrm{m\,s^{-1}})^2} = 1.62\times10^{-25}$ kg mass $= \frac{1.62 \times 10^{-25}\mathrm{kg}}{1.67\times10^{-27}\mathrm{kg}}$ mass = 97 times that of a proton Alternative: mass of proton = $\frac{1.67\times10^{-27}\mathrm{kg}\times(3\times10^8)^2\ (\mathrm{m\,s^{-1}})^2}{1.6\times10^{-19}\mathrm{J\,eV^{-1}}}$ = 0.939 GeV/c^2 100 ×0.939 GeV/c^2 = 94 GeV/c^2 which is just a bit more than mass of Z boson.	(1) (1) (1) (1)	4
13(b)	• Mass-energy is conserved **Or** refers to $\Delta E = c^2 \Delta m$ • Need for large amounts of energy to create a high-mass particle **Or** Need more energy because mass of Z much greater than mass of proton(s) [accept 97 times] • (Additional) energy comes from the <u>kinetic</u> energy of colliding particles	(1) (1) (1)	3
13(c)	• At speeds close to the speed of light • there is a relativistic increase in lifetime **Or** time dilation occurs [do not accept dilution]	(1) (1)	2
	Total for question 13		**9**

Question Number	Answer	Mark
*14	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content.	6

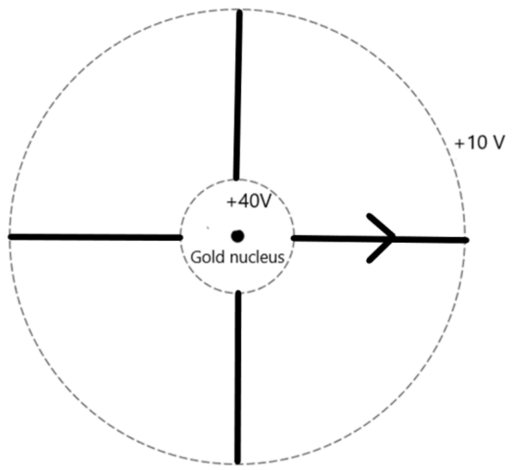
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	Max linkage mark available	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).

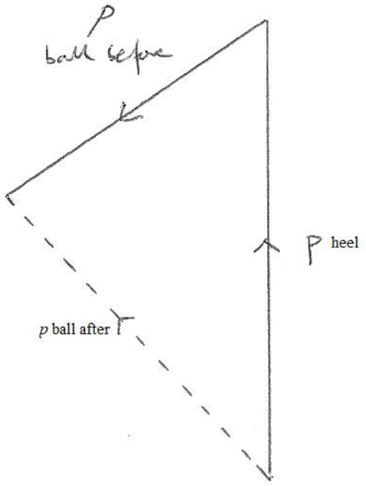
	Indicative content: IC1: Change in flux linkage as magnet falls (through each tube) **Or** (magnetic) field lines cut the metal IC2: EMF induced (in each tube) IC3: Tube(s) made of conducting material, so there is a current **Or** Tube provides a closed circuit, so there is a current IC4: Magnetic field associated with this current IC5: Upward force exerted on magnet as the field is such to oppose the change that creates **Or** Due to Lenz's law there is a force opposing the motion of the magnet IC6: Magnet takes less time to fall through Tube B because the slit reduces the number of paths for current in the conductor	
	Total for question 14	**6**

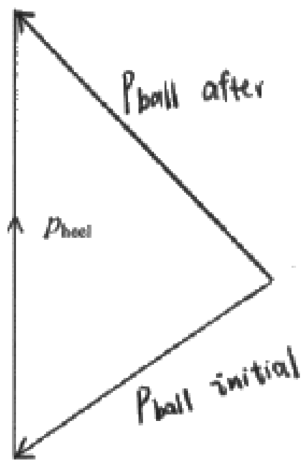
Question Number	Answer	Mark
15(a)	MAX 2 for beta and 2 for gamma Beta • Beta particles are much less massive than alpha particles **(1)** • So beta might be deflected by the electrons (surrounding the nucleus of gold) **(1)** **Or** • Beta more penetrating **(1)** • So beta less likely to interact / scatter / deflect **(1)** **Or** • Alpha has double the charge (of beta) **(1)** • So for alpha deflecting force will be more (for same separation) **(1)** Gamma • Gamma isn't charged **(1)** • So gamma will not deflect at all (electrostatically) **Or** gamma will not experience any electrostatic force **(1)** **Or** • Gamma more penetrating **(1)** • So gamma less likely to interact **(1)**	**3**
15(b)(i)	• At least four straight radial lines between the two potential lines **(1)** • Equidistributed / equispaced **(1)** • At least one arrow pointing away from nucleus **(1)** Example of diagram 	**3**
15(b)(ii)	• Measures the distance to both potential lines from centre of gold nucleus **(1)** • Use of $V = Q/4\pi\varepsilon_0 r$ **(1)** • This line is in the correct place as $V \times r$ is the same for each case **(1)** Example of calculation Measures distance to 40 V = 1 cm and distance to 10 V = 4 cm So $k = 40 \times 1 = 40$ and $k = 10 \times 4 = 40$	**3**
15(b)(iii)	• Charge on alpha particle is 2e **(1)** • Use of potential difference = W/Q **(1)** • W = 60 (eV) **(1)** Example of calculation Change in potential = 40 V − 10 V = 30 V Change in potential energy = 30 V × 2e = 60 eV	**3**
	Total for question 15	**12**

<table>
<tr><th>Question Number</th><th>Answer</th><th></th><th>Mark</th></tr>
<tr><td>16(a)</td><td>
• Use of $\omega = \Delta\theta / \Delta t$
• Use of $v = r\omega$
• $v = 4.7\ \mathrm{m\,s^{-1}}$
Or
• Use of $\Delta s = r\,\Delta\theta$
• Use of $v = \Delta s / \Delta t$
• $v = 4.7\ \mathrm{m\,s^{-1}}$

<u>Example of calculation</u>
$\omega = 1.3\ \text{rads} / 0.22\ \text{s} = 5.9\ \mathrm{rad\,s^{-1}}$
$v = 5.9\ \mathrm{rad\,s^{-1}} \times 0.80\ \text{m} = 4.73\ \mathrm{m\,s^{-1}}$
</td><td>(1)
(1)
(1)</td><td>3</td></tr>
<tr><td>16(b)(i)</td><td>
• Use of $p = mv$
• Use of the scale 1:2
• Adds scaled line at 56° to correctly represent initial momentum
• Adds scaled line to correctly represent final momentum of ball
• Concludes that conservation of momentum is obeyed as their diagram completes a triangle
Or Concludes that conservation of momentum isn’t obeyed as their triangle has a small gap

OR
• Use of $p = mv$
• Use of the scale 1:2
• Adds scaled line at 56° to correctly represent initial momentum
• Adds line to complete triangle
• Concludes that conservation of momentum is obeyed as their line is the right length
Or Concludes that conservation of momentum isn’t obeyed as their line is not the right length

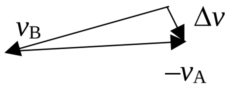
<u>Example of vector diagram</u>


Or


<u>Example of calculation</u>
Momentum ball before = $0.16\ \text{kg} \times 13\ \mathrm{m\,s^{-1}} = 2.08\ \mathrm{N\,s}$, length = 4.16 cm
Momentum ball after = $0.16\ \text{kg} \times 16\ \mathrm{m\,s^{-1}} = 2.56\ \mathrm{N\,s}$, length = 5.12 cm
</td><td>(1)
(1)
(1)
(1)

(1)</td><td>5</td></tr>
</table>

16(b)(ii)	• Use of $E_k = \frac{1}{2}mv^2$ • Uses total kinetic energy before = E_k heel + E_k ball before • Total kinetic energy before = 21.0 (J) **or** kinetic energy after = 20.5 (J) • Elastic collision because total E_k before = E_k after **Or** Not elastic collision total E_k before is not the same as E_k after (**both** figures must have been correctly calculated) <u>Example of calculation</u> E_k heel = ½ × 3.0 Ns × 5.0 m s^{-1} = 7.5 J E_k ball before = $\frac{1}{2}$0.16 kg × 13^2(m s^{-1})^2 = 13.5 J E_k after = $\frac{1}{2}$0.16 kg × 16^2(m s^{-1})^2 = 20.5 J Total kinetic Energy before = 21.0 J	**(1)** **(1)** **(1)** **(1)**	**4**
	Total for question 16		**12**

Question Number	Answer		Mark
17(a)	• Vector velocities at the two positions as part of a triangle and third side identified as Δv • Small angle, so $\Delta v/v \approx \theta \approx \sin\theta$ **Or** Small angle, so arc AB ≈ chord AB **Or** Small angle, so $s/r = \theta \approx \sin\theta$ • Use of $\theta/t = \omega$ and $v = r\omega$ **Or** Use of similar triangles and $\theta = s/r$ and $s/t = v$ • Use of acceleration $a = \Delta v/t$ • Suitable algebra to show $a = v^2/r$ <u>Example of derivation</u>  Small angle, so $\Delta v/v \approx \theta \approx \sin\theta$ $\theta/t = \omega$ So $\theta = \omega t$ But $v = r\omega$ So $\theta = vt/r$ $\Delta v/v \approx \theta$ So $vt/r = \Delta v/v$ $a = \Delta v/t = v^2/r$	**(1)** **(1)** **(1)** **(1)** **(1)**	**5**
17(b)(i)	• Idea that vertical component of lift force equals weight of aeroplane • Vertical component of resultant force is zero, so aeroplane does not accelerate vertically **Or** Vertical component of resultant force is zero so it would remain flying horizontally • Horizontal component of lift force acts as centripetal force **Or** Resultant force on aeroplane is horizontal and acts as centripetal force **Or** Horizontal component of lift force acts at 90° to motion • So it follows a circular path (dependent on MP3)	**(1)** **(1)** **(1)** **(1)**	**4**
17(b)(ii)	• Use of $W = mg$ • Use of $L\cos\theta = mg$ • Use of $L\sin\theta = mv^2/r$ • Radius = 3.2×10^5 m <u>Example of calculation</u> $W = 4.1 \times 10^5 \times 9.81 = 4.02 \times 10^6$ N $L\cos 5.2° = 4.02 \times 10^6$ N $L = 4.04 \times 10^6$ N $mv^2/r = 4.04 \times 10^6 \text{ N} \times \sin 5.2° = 3.66 \times 10^5$ N $3.66 \times 10^5 \text{ N} = 4.1 \times 10^5 \times 530^2 / r$ $r = 3.15 \times 10^5$ m	**(1)** **(1)** **(1)** **(1)**	**4**
	Total for question 17		**13**

<table>
<tr><th>Question Number</th><th>Answer</th><th></th><th>Mark</th></tr>
<tr><td>18(a)(i)</td><td>• Use of $E = V/d$
• $V = 4.5 \times 10^4$ V

<u>Example of calculation</u>
$7.5 \times 10^5 = V / 0.06$
$V = 4.5 \times 10^4$ V</td><td>(1)
(1)</td><td>2</td></tr>
<tr><td>18(a)(ii)</td><td>• Use of $E = F/Q$
• Use of $\Delta W = F\Delta s$ with s = 3.0cm
• Use of $\Delta W = E_k = ½mv^2$
• $v = 5.2 \times 10^5$ (m s^{-1})

Or

• Use of $E = F/Q$
• Use of $F = ma$
• Use of $v^2 = u^2 + 2as$ with s = 3.0cm
• $v = 5.2 \times 10^5$ (m s^{-1})

Or

• Use of $V = W/Q$
• Understanding that $V = 2.25 \times 10^4$ V (ecf from (i))
• Use of $\Delta W = E_k = ½mv^2$
• $v = 5.2 \times 10^5$ (m s^{-1})

<u>Example of calculation</u>
7.5×10^5 Vm^{-1} = F / 1.6×10^{-19} C ($F = 1.2 \times 10^{-13}$ N)
$\Delta W = 1.2 \times 10^{-13}$ N × 0.03 m ($\Delta W = 3.6 \times 10^{-15}$ J)
3.6×10^{-15}J = ½ × 2.7×10^{-26} kg × v^2
$v = 5.16 \times 10^5$ (m s^{-1})</td><td>(1)
(1)
(1)
(1)

(1)
(1)
(1)
(1)

(1)
(1)
(1)
(1)</td><td>4</td></tr>
<tr><td>18(b)(i)</td><td>• The direction of electric force will be downwards so magnetic force must be upwards
• and the magnetic field is into the page
(dependent on MP1)</td><td>(1)

(1)</td><td>2</td></tr>
<tr><td>18(b)(ii)</td><td>• Use of $F_E = EQ$
• Use of $F_M = BQv$
• B = 0.021 T

<u>Example of calculation</u>
$F_E = 10500$ V m^{-1} $\times 1.6 \times 10^{-19}$C = 1.68×10^{-15} N
$B \times 1.6 \times 10^{-19}$C $\times 5.0 \times 10^5$ m s^{-1} = 1.68×10^{-15} N
B = 0.021 T</td><td>(1)
(1)
(1)</td><td>3</td></tr>
<tr><td>18(c)</td><td>• Isotopes have different masses
• The magnetic force will be the same because charge is the same
Or $r = mv / Bq$ and B, q, v are all the same
• Different mass will lead to a circle/path with different radius/deflection (so only one isotope is detected)</td><td>(1)

(1)

(1)</td><td>3</td></tr>
<tr><td></td><td>Total for question 18</td><td></td><td>14</td></tr>
</table>

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